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ABSTRACT

Student-designed laboratory exercises have become an important part of the physics classes at Piedmont Virginia Community College. Rather than filling in the blanks of a laboratory workbook, students are required to design and carry out weekly experiments which relate to the physics concepts being studied. Using computers, standard laboratory equipment, and other assorted tools and materials, students work together in teams with the teacher acting as facilitator or guide, asking questions or suggesting additional ideas for the experiments. Rather than taking their data and notes home to produce a clean report, students write their laboratory reports during lab time, reporting errors as well as successes. Though students were hesitant about the approach at first, they later adopted it enthusiastically, with many students giving the laboratory exercises the highest ratings of the course. The success of the exercises in helping students to take more ownership of the course and become more actively engaged with the content has been evidenced by long-term changes in students' investigative behavior. Guidelines for the laboratory exercises are included. (EJV)

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by

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Student Designed Laboratory Exercises for Physics

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May 12, 1986

Abstract: Student designed laboratory exercises have come to be an important part of the physics classes at Piedmont Virginia Community College. Laboratory groups were made responsible for designing and carrying out their own unique laboratory investigations each week. Students were hesitant at first, but later adopted the program enthusiastically. Numerous indications of deep student involvement and engagement with the subject matter have been observed. According to student evaluations, the laboratory exercises are one of the most highly rated parts of the physics courses.

When I began teaching physics at Piedmont Virginia Community College in 1983, I was faced with a dilemma. From earlier experience, I had seen that students' attitudes towards physics, especially required physics courses such as the ones I would be teaching, left much to be desired. How could I encourage the students to take more ownership of the course and become more actively engaged with the content?

I wanted to develop and implement a teaching strategy to involve my physics students more deeply with their learning. In particular, I felt that it was important to discourage a "plug and chug" approach to physics, in which the mental activity of the students consists of selecting an equation, substituting values into it, and calculating a result. Rather, I wanted students to be involved with understanding the concepts being studied.

In order to accomplish this, I designed a laboratory program which required the student lab groups to design and carry out their own experiments. This placed the responsibility for learning and understanding squarely on the students.

The Program

At the beginning of the school year, I described to the students my laboratory requirement for each week: to design and carry out an experiment which will help with the understanding of the physics concepts we were studying. (See laboratory handout attached as an appendix.)

Naturally, this was met with some initial resistance, because it was an extremely unfamiliar type of assignment. (Most science students are accustomed to filling in the blanks of a laboratory "cookbook.") As I explained more details of the program, the students seemed to become aware of many attractive possibilities, and expressed a willingness to give it a try.

I arranged for computers, classical laboratory apparatus, and assorted tools and materials to be available, as well as special equipment requested for particular activities. The powerful Logo computer language was introduced to the students as an interactive tool for exploring physics concepts. I included in each lecture a number of suggestions for laboratory activities.

During the lab, I filled the role of a facilitator or guide, rather than a lecturer (as in the previous class meeting). If a group was having difficulty getting started, I made a few suggestions. In occasional extreme cases, I gave detailed requirements.

As students began to assemble their apparatus, I asked questions designed to increase their understanding of specific physics concepts, and give them additional ideas for their activity.

During the laboratory period, I encouraged students to visit other experiments and learn what their classmates were doing. This stimulated interactions which engaged the students deeply in the tasks at hand. When possible, I suggested that students use the results of other groups, with appropriate citations in their reports. For example, if one group was designing an instrument to measure the strength of a magnetic field, another group might use the instrument to confirm the results of their magnetism experiment in an additional way.

I required that the student groups write their laboratory report "as they go" and submit it at the conclusion of the activity, rather than taking their data and notes home and recopying them into a "clean" report. This action modeled the maintenance of research journals in actual research laboratories. It also freed the students to concentrate on the work and not on the superficial appearance of the presentation of the results.

Additionally, it encouraged them to report their "goofs" as well as their triumphs. Some of the most important learning in science is from things that do not work as they "should." I feel it is important for students to be free to explore this important "why."

I graded the laboratory reports rather liberally, to encourage innovation and creativity. I did not want a student to worry if an innovative experiment did not perform as expected. The process was as important as the product.

I suggested to the students that the opportunity for ownership of their experiments and for flexibility in their actions were important ingredients in their learning.

Did It Work?

The effectiveness of this program was measured by indirect means and informal observations.

After the first two or three laboratory meetings, students began to sense how they could use apparatus from home or from the job in their experiments. Several students related the physics concepts to their hobbies or career fields, and designed extremely creative experiments. They began to relax and enjoy their laboratory meetings.

Often, students stopped me in the hall between classes and told me excitedly about an idea they had for the coming laboratory. In addition, many students chose tc extend their laboratory work on their own time for extra credit. I believe this enthusiasm was an indication of affective learning, a powerful companion to understanding.

During laboratory meetings well into the course, I observed students taking an interest in the experiments of others, and asking questions about them on their own initiative. This type of behavior is not observed (and probably not encouraged!) in more rigidly organized laboratory classes.

Part of my overall grading scheme consisted of a quarterly self-evaluation by each student. The result was accepted as 10% of the final grade in the course. In the narrative section of this self-evaluation, extremely positive spontaneous comments about the laboratory system often appeared. Typical comments were, "I love the way we do our labs!" and "Don't change the lab system. I enjoy making up my own experiments."

I have also observed longer term changes in student investigative behavior over the course of a year. Here is a brief case study as an example.

> *The third quarter of our physics program includes the study of magnetism. One particular lab group had made heavy use of Logo and the computer. For their magnetism lab, however, they decided to use classical apparatus instead for an activity to duplicate Oersted's famous experiment (sending an electric current through a wire to establish a magnetic field outside the wire). They set up the apparatus and used a compass to detect the direction of the magnetic field at various places. At one point, however, the compass needle behaved strangely. After some discussion, one student suggested that perhaps their magnetic field had cancelled out the magnetic field of the earth. They did not*

have an understanding of how this could happen, so they went to the computer and used Logo to set up a current-carrying wire in an external magnetic field. By studying the magnetic lines of force, they saw immediately how the field has a value of zero at one particular point. They then returned to their apparatus, performed a few other measurements, and realized that, if they had cancelled the earth's field, they should be able to predict its value! After a few moments of calculating, they produced a value which was within 10% of the accepted magnitude. They were quite excited at this accomplishment! Needless to say, this result was not anticipated at the beginning of the lab.

The general behavior of the students in this case study was quite different at the beginning of the course of study. Earlier, they were hesitant, fearful of "making mistakes," and generally tightly constrained in their thoughts and actions. As a result of their increasing self-confidence during the year, they felt free to explore the questions which they encountered in the course of their magnetism experiment. In this case, the direction of the entire lab activity was changed as a result of their curiosity about the behavior of the compass needle.

I feel that such long term changes in investigative behavior were indications of student willingness to become more involved in the understanding of the physics concepts under study.

Occasional extraordinary performance by students was also observed. In 1985, for example, two students got interested in the motion of an airplane seen in a photograph and the mechanism of a mass driver for propelling matter from the moon into orbit. They developed powerful computer models of these phenomena using Logo and explored a number of different configurations. They wrote a joint paper about these projects and their other physics course investigations with Logo which was accepted at an international conference at the Massachusetts Institute of Technology that summer.

Finally, an article I wrote on the combination of using Logo and self-designed laboratory exercises was published as the cover article of the January 1986 issue of *The Physics Teacher* journal, and was well received. A number of students were involved in the production of the article and the accompanying photographs. They were extremely proud that they were doing something important enough to get published.

Conclusion

In summary, the concept of self-designed laboratory experiments has become a comfortable one to my students. As a result, they seem to be much more involved with their learning, and seek personal understanding of the physics concepts we studied. How could I ask for more?

With my students, I have designed my own laboratory strategy, and I want to remain free to explore additional possibilities. In this way, I can learn from my students, and strive for an even deeper understanding of the mechanisms which affect their learning.

Laboratory Guidelines

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Laboratory exercises are conducted in room 136. In most instances, six laboratory stations are established, with equipment available related to the concept under investigation. In many cases, you can choose a computer exercise, one using regular laboratory apparatus, or a combination of both.

You and your lab group are expected to organize, design, and carry out an investigation based on physics concepts recently studied, and write up and submit a lab report. Since the lab time available is limited, you should have some idea for your project in mind beforehand. The more advance planning and thinking you do, the better. In previous courses, students often brought in supplementary apparatus from the home and job for lab use. Should you choose a computer exercise, several specific suggestions are available.

The lab report is written in the form of an informal research journal or diary, and is turned in at the end of the lab period. This means that the main body of the report is a narrative of what takes place during the investigation, and is written *as it happens*. This includes a description of all actions and the results of all measurements, regardless of whether they are "successful" or not. In fact, the action of the group to recover from "unsuccessful" actions is one of the more important aspects of the laboratory exercise.

The report should include as a minimum:

a. Names of all lab partners
b. Course name and date of lab exercise
c. Title of lab
d. Physics concept(s) explored and object of lab
e. Details (journal) of exploration or investigation, with data
f. Errors and results
g. Conclusions
h. Extensions (how the lab could be applied in a particular career field, how it could be modified or enhanced, etc.)

I prefer that all reports be written in ink, with any changes lined through.

The reports are graded as follows:

0. Report not turned in, or totally unsatisfactory
80. Lab requirements satisfied
90. Extremely high quality work, neat, correct grammar
100. Exceptionally creative, complete, clearly far beyond minimum lab requirements

Since computers are available often, you may want to purchase one or more computer diskettes for storing your work. These are available singly and in boxes of ten from the PVCC book store. The diskettes must be formatted before they can be used. I will help you format your diskettes during the lab period.

Computers are also available in the computer labs (rooms 601 and 603) for work outside of class.

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